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Health-Related Aspects of Integrated Pest Management

by Ray F. Smith* and Donald J. Calvert*

Basic concepts and philosophy of integrated pest management are presented in order to dispel several misconceptions and to provide the necessary background information for discussion of its relationship to the health-related effects of pesticide use. Implications for human health of current pesticide practices in Central America are examined to illustrate major problems associated with the injudicious use of insecticides, i.e., human pesticide poisonings, development of insect resistance, and persistence in the environment. Mitigation of these problems would ideally be achieved through the efforts and cooperation of a multidisciplinary team of scientists and technical people in the medical and agricultural sciences. The dilemma associated with the development of integrated pest control systems in developing countries is discussed. The FAO/UNEP Global Programme was reviewed.

The general aspects of integrated pest management, their significance in crop protection, and problems associated with the establishment of this approach and how pest control activities employed in crop protection relate to the health of man and the environment will be discussed.

First, integrated pest management must be defined and explained, since it is not universally understood. Integrated pest management is simply a broad ecological approach to pest control. It attempts to utilize a variety of control technologies compatibly in a single pest management system. For that reason, there is nothing new about the approach. Entomologists for more than a century have known that pest control must have an ecological basis, and their wisdom has been confirmed in more recent years.

A fundamental concept in integrated pest management is the importance of establishing realistic economic injury levels for a particular pest on a given crop. These levels, once established, are used to determine the need for control actions against that pest. At the same time, all possible is done to protect and preserve naturally occurring biotic mortality agents such as parasites, predators, and pathogens. When artificial controls are needed, for example, chemical pesticide applications, they are employed in as selective a manner as possible, and only when their use is economically and ecologically justified. The ultimate objective of the integrated pest management system is to produce the optimum crop yield of high quality at minimum cost, taking into consideration the ecological and sociological constraints in that particular agroecosystem and the long-term preservation of the environment. This last sentence describes the goal of integrated pest management.

The basic strategy of the more sophisticated pest management systems is to manage the pest populations at noneconomic densities so as to optimize economic returns consistent with minimal environmental damage. To achieve this, they have used a variety of approaches: first, to develop a scientific understanding of the significant biological, ecological, and economic processes in the growth of the crops and the population dynamics of the pests and the factors affecting them, and of the interactions among these processes and factors; second, to develop tactics which are ecologically compatible for use in suppressing major pests and which can be expected to reduce the use of broad spectrum chemicals and lessen the adverse effects of pesticides; third, to develop better methods of collecting, handling, and interpreting relevant biological, meteorological, and crop production data; fourth, to utilize systems analysis and modeling as a central unifying and research-guiding tool in the pursuit of the main goal and its subsidiary goals;

*Department of Entomological Sciences, University of California, Berkeley, California 94720.

and finally, to build models of the crop production and pest systems, integrate these with economic analysis (impact, etc.), and conduct pilot tests on the use of the combined management models for each crop system. Croft and Huffaker elaborate these steps in more detail in their discussion of integrated pest management in the United States (*1*).

For further clarification of integrated pest management, we are compelled also to describe what integrated pest management is not. It is not sole reliance on predators or parasites, although natural enemies are utilized and fostered as much as possible in the system. In other words, it is not what has been called "nature's way" although we take many leads from Mother Nature.

It is not classical biological control (i.e., the importation of natural enemies into new areas), although this technology is brought into use when possible, and the biological control specialists are strong advocates of integrated pest management.

It is not the use of the sterile insect release method, nor the use of pheromones, nor the use of juvenile hormones or hormone analogs, or other such biologically based methods of control, although eventually we may be able to use such techniques widely in integrated pest control and are striving to do so.

It is not the elimination or banning of DDT, chlordane, or any other chemical pesticide, although in a particular integrated control system it may be necessary to restrict the use of some or most pesticides and not use others.

It is not the development over a long period of time, with much research effort, of a completely new pest control system which then is established in place of the old system; rather the developmental process is a series of incremental steps which gradually modify the old existing system.

Another aspect of this problem of the definition which merits at least brief discussion is the scope of integrated pest management. As most of the development of integrated pest management over the past 30 years has been by entomologists concerned with control of insects, most of their examples and analyses have related to insects. However, even the most narrow of provincially minded entomologists realizes (even though he doesn't vocalize it too well) that the control of insects is only part of crop protection. Of course, we also know that crop protection is only a part of the crop production system. In spite of the obviousness of these points, it is hard to find reference to them in all the millions of words said and resaid about integrated pest management. Only recently has the broad multidisciplinary approach emerged clearly.

At the FAO Symposium on Integrated Pest Control in 1965 in Rome, Grison (*2*) gave a paper entitled, "Importance of Interdisciplinary Approach," but he was really talking about an interdisciplinary attack on a single insect problem. Although plant protection in Europe is traditionally handled on a multidisciplinary basis, this has not greatly influenced the development of the philosophy of integrated pest management. Only in the last four or five years has there been a change from such a strict entomological viewpoint, e.g., the FAO Panel of Experts on Integrated Pest Control now has disciplines other than entomology represented; the A.A.A.S. symposium in San Francisco in 1974 was multidisciplinary; and the UC/AID Pest Management project has fielded multidisciplinary teams to analyze pest control problems in developing countries.

It should be clear from the preceding discussion that integrated pest management utilizes the same tools as do other approaches to pest control—i.e., pesticides, natural enemies, resistant varieties. It thus has no special relationship to human health effects of pest control except that the integrated pest management approach usually reduces the intensity of pesticide use. Insofar as these pesticide uses may be a risk to human health, the lowered level of use lowers the degree of risk.

To illustrate the degree and kinds of risk to which a community may be exposed from the inordinate and injudicious use of pesticides, the problems encountered by El Salvador may be looked upon as being representative of the situation that is found in many other countries as well. El Salvador is a small country situated on the Pacific coastal plain of Central America with a population of approximately 3.8 million people. The agricultural sector of the economy is still heavily dependent on the production of coffee, but substantial diversification into other crops, particularly cotton and sugar, has occurred in the last few years. Other major crops are maize, beans, and sorghum, and there is a growing livestock industry.

A great deal of pesticides is used by agricultural interests for controlling pests that attack food and cash crops and by public health authorities for the control of insect vectors of malaria. It has been estimated that 8 million pounds of pesticides are imported into this country annually, the majority of which is used on cotton. The intensive use of insecticides on this crop, frequently amounting to over 20 applications a season, has resulted in numerous cases of human poisonings reported annually. Table 1 presents the number of recorded hospitalized cases of pesticide poisonings for 7 years (during the

Table 1. Hospitalizations for pesticide poisoning in El Salvador, 1963–1972.

Year	Nonfatal cases	Fatal cases
1963	1104	11
1964	965	2
1965	938	1
1969	584	7
1970	474	7
1971	586	10
1972	2787	5

period 1963–1972), as determined by the public health authorities in the Ministry of Health (*3*) of El Salvador.

The great increase in reported incidence of pesticide poisonings in 1972 is thought to have been due to a combination of several factors, among which was the introduction of ultra-low volume application of parathion combined with a worker reentry period that was too short and unusual weather conditions. The data for 1972 may be considered to be especially reliable because of an independent survey conducted by representatives from the Ministry of Labor of El Salvador for that year which produced comparable results (*3*).

A second problem associated with the use of pesticides is that of insect resistance. Development of resistance to an insecticide in a pest species either leads to the use of higher dosages of the chemical, or to its being applied more frequently, or to its substitution by a more toxic pesticide. Adoption of any of these measures would result in a greater contamination of the environment and a higher degree of risk to humans.

The occurrence of resistance in species which are vectors of human diseases is a special problem with severe implications for human health. Not only does the use of higher dosages or more toxic chemicals create an increased hazard to humans, but in the event the vector becomes resistant to most or all of the available chemicals, then a return to previous high levels in the incidence of the disease transmitted by that species may be expected. This latter possibility may be occurring now in El Salvador with respect to malaria. The mosquito vector, ***Anopheles albimanus***, has high resistance to organophosphate compounds (*4–7*) and has recently been found to have developed resistance to the carbamate compound, propoxur (*6*). Due to the high prevalence of resistant mosquito populations in many parts of this country, malaria is now being controlled in these areas through the use of drug therapy. Statistics for the year 1974 show a nearly twofold increase in the incidence of malaria from the previous year (a total of 66,691 positive cases of malaria in a sample of 478,553). The area of high incidence of malaria in El Salvador is along the coastal plain where cotton is also produced. Georghiou (*6*) has suggested that the agricultural use of parathion on cotton has facilitated the development of a cross-resistance of this mosquito to propoxur.

Contamination and persistence in the environment is another major problem deriving from the widespread use of pesticides. Varying residual amounts of these chemicals and their breakdown products may remain in the soil for many years, as well as being present in food, air, and water. This ubiquitous presence in the enviornment is a continual source of chronic exposure to the human population. The effects of this exposure are not yet adequately known. Experimentation with animals have shown that several chemicals are tumorogenic and some are marginally carcinogenic. However, a cause-and-effect relationship between pesticide chemicals and the occurrence of cancer or other diseases in man has not been demonstrated.

El Salvador has a sizeable meat industry, with the main grazing pasture located on the coastal plains adjacent to the areas of cotton production. Since the cattle are frequently fed on cotton and corn stalks after harvest, it was a common occurrence to find that contamination of the beef with residues of pesticides previously applied on those crops had resulted. Reports of excessive pesticide residues in meat were numerous (*3*), and on several occasions exportation of beef lots to the United States had been prohibited on account of these high levels.

Surveys in other parts of Central America have also indicated that human pesticide poisonings are a serious problem. Again, cotton is a major crop in these countries and receives many applications of ethyl and methyl parathion mixtures during the growing season. There are several studies that report the number of pesticide poisoning cases for this region, for example, the data of Vandekar (*8*) for Guatemala and Nicaragua (Table 2).

Table 2. Pesticide poisoning cases for Guatemala and Nicaragua (1968–1971).

Year	No. of cases	
	Guatemala	Nicaragua
1968	1374	–
1969	837	258
1970	659	221
1971	1100	356

This matter is a worldwide problem and certainly is not limited to less developed countries. From a global point of view, reports of pesticide poisoning in workers and in the general population are numerous. Although accurate statistics are not available, it is obvious that the problem is both extensive and serious. The World Health Organization has estimated that there are approximately 500,000 cases occurring annually with greater than 1% mortality rate. Yates (*9*) gave the results of a California Departments of Food and Agriculture and Health study citing reported cases of pesticide-related occupational illness in the state of California in 1973 (Table 3).

Table 3. Pesticide-related occupational illness in California (1973).

Occupation	Illness, no. of cases				
	Systemic	Skin	Eye/Skin	Eye	Totals
Ground applicators	187	103	13	121	424
Mixer loader	121	19	3	22	165
Field worker	45	94	0	18	157
Nursery greenhouse	18	71	1	22	122
Other occupations (11)	294	165	16	141	606
Totals	665	452	33	324	1474

These examples dramatically illustrate the pervasive influence and the many ramifications that attend the use of pesticides. The introduction and development of integrated pest management programs in countries where pesticide problems are severe would, we believe, mitigate the harmful effects of their use.

This integrated pest management approach can be introduced in very simple ways at first which do not require highly sophisticated pest control technology. However, when such technology exists together with the necessary infrastructure, it permits the relatively easy acceptance of new technology. This is important for some of the new pesticides and other control technologies discussed in the meeting, such as: (1) the application of very low application levels appropriate for the new potent pyrethroids (this cannot be handled by traditional crude techniques of application); (2) the special hazards of certain other new pesticides, which can be best handled by experienced, trained personnel; (3) special timing of application which is related to population levels or seasonal progression. This technique is easily effected in supervised control systems.

The reduced levels of pesticide usage which characterize most integrated pest management has another health-related aspect. The lowered pesticide usage reduces the selection pressure toward strains of pests resistant to the pesticides. Thus, the need to use higher and higher dosages as resistance develops in the pest population or the need to replace the no-longer effective pesticide with other more toxic ones is avoided or postponed significantly.

Some integrated pest management development projects have included another health-related aspect as a significant part of their activities. This is the agro-medical team approach to pesticide management.

Pesticide Management is the technology concerned with the safe, efficient, and economic use and handling of pesticides from the time manufacture is completed until final utilization and disposal. Included in this complex process are formulation, packaging, transport, storage, official registration for use and sale, selection for use, application, and the disposal of containers and unwanted material. In addition, pesticide management addresses the problems of residues in food and the environment and their impact on the welfare of man. Pesticide management must be considered an integral component of sound pest and vector management.

It has now been demonstrated in a number of countries that pesticide management is achieved ideally through a multidisciplinary attack known as the agro-medical team approach. This approach utilizes the combined expertise of the medical and agricultural sciences in an attack to the pesticide management problem common to agriculture, health and society. The logic of this agro-medical team approach is seen in the fact that the well-being of a community is found not only in its economic status but in its nutritional and health status as well. Sound pesticide management can make significant contributions to the economic, nutritional, and health status at the village, city, country, and regional levels.

Certain fundamental concepts underlie the agro-medical approach to pesticide management. Some of these may sound unworkably idealistic, calling as they do for human beings to rise above their parochial interests to work together toward the goal of the common good, but there is an urgency brought on by current conditions that demands such as response on everyone's part.

The first concept or premise is that the problems of physical health and economic well-being of the rural area are inextricably interrelated so far as man is concerned. Without food and money, the most beautiful environment appears to man to be but desolation. In like manner, riches cannot compensate for loss of health. Thus the concept of agromedicine embodies a "holistic" approach to community well-being involving food production and protection of health of both man and his environment. We are of course, considering here the rural areas.

Deriving from this concept is the premise that achievement of the implied goals calls for a coordinated interdisciplinary approach. In the beginning certain primary disciplines must lead the way. The smallest such group is that made up of an agriculturist (biologist), health practitioner, and chemist. This comprises our base agro-medical team. As we see it, in many countries the primary and sometimes most effective contact with rural people is the agricultural worker—either government extension or industry representative. In the agro-medical approach, we believe this individual should be regarded as and given the responsibility for primary community care in the areas of food production and preventive health practices. He supplants neither the public health practitioner nor the agricultural expert but serves as their entré in dealing with the problems.

It is easy to see this responsibility for the government worker but how about the industry representative? Here we believe the interests of government (society) and industry converge. Consider the benefits (profits) that can and would accrue to industry from a healthy productive and economically sound community in which resides a reservoir of good will toward the industry (company) that helps it.

Our community worker must be trained in pesticide management agriculture and the practice of hygienic measures and it is here where the agro-medical team concept comes into play. These teams provide the necessary short-term training in relevant fields and practices and the necessary support services such as analytical chemistry, field investigations, and health care delivery.

The next element is that of the agro-medical team beginning with the district or region and continuing to the national level. At each level the breadth of expertise and capabilities to provide service and do research increases. Conjoined at the different levels are the various government agencies for research, regulation, universities, and extension, and as full working partners the complex of related industries as a coordinating council. This may be accomplished by the formation of a supra-team of representatives of each group with resources of expertise to provide suggestions on needed regulation, research training and technical assistance. But more, this group can invoke cooperation and assistance at the international level.

This agro-medical team approach is being developed in El Salvador, Indonesia and the Philippines. Plans are underway for the development in other areas.

Croft and Huffaker have described (*1*) the status of integrated pest management in some detail in the United States. What is the status in the rest of the world? In many parts of the developed world, in western Europe, in the Soviet Union, in Japan, in Australia, integrated pest management is considered to be a sound approach to crop protection, although the examples of practical application are few and limited to a few crops. Much research is nevertheless underway. In western Europe, the application phase has been reached on apples, peaches, cereals, sugar beets, and glasshouse crops.

The establishment of integrated control in the developing tropical areas of the world has been exceedingly slow. In most of the countries of the tropics, there is recognition of the importance of plant protection and of the huge losses in food from the attack of a great variety of pests; but unfortunately the farmers who produce the food crops are rarely in a position to take action for pest control, especially if it means an economic outlay. The situation with the estate crops is different, and progress in integrated control has been made on tea, oil palm and a few other crops. In general, in the tropics, where research on plant protection has been attempted, there has been a very heavy reliance on the development of resistant varieties often to the neglect of other tactics of pest control. Even so, the dangers from pests associated with the very substantial reductions in the genetic base are disturbing (*10*).

In most of the tropical countries, the level of pesticide use has been quite low except on a few crops such as cotton, high value vegetable crops, and certain estate crops. However, at this time of great need to increase food production, many of the tropical countries wish to increase their use of pesticides. Unfortunately, this desire to use more pesticides coincides with worldwide shortages and especially increased costs of pesticides. The origins of this problem are complex, but it applies to almost all types of pesticides, and it is not likely to be alleviated soon. This situation demands that we use our supplies of pesticide in the most effective manner possible. We must institute programs in the conservation of pesticides where every gram is used so that it will have its most significant impact. This situation will become an added stimulus to the development of integrated pest management because it is the best way to conserve pesticides.

Finally, a few words about the integrated pest control dilemma particularly as it exists in developing countries of tropical areas: integrated pest control systems do not just happen; they come about through the careful ecological analysis of pest problems as they exist in the field. Programs of research for the development of integrated pest control systems must relate to the full complexity of these field problems. No amount of sophisticated laboratory research will produce an integrated pest control system unless the research is intimately related to the field problem and has continuing feedback from the field. At the same time, research on the problem in the field can be quite complicated in establishing the complex relationships that exist in the agroecosystem, i.e., between pest and crop; pest and natural enemies of the pest; the pest, its natural enemies, and crop diversity; such relations must also be considered together with other crops and the climate, and the economic and political aspects. Herein lies the dilemma facing the crop protection specialist in a developing country. How can he, with his limitations in facilities, skilled manpower, and other resources, possibly explore adequately such complex problems? It often seems better for him to seek some other solution. To this we can only say that to our knowledge, every operational integrated pest control system in existence today has in fact had a relatively simple yet effective beginning. The first programs were a best approximation of an ideal system based on the then available knowledge. This approximation was then tested and where difficulties were encountered, these difficulties were posed as questions for the parallel solution-seeking research. In this way, even when resources are rather limited, an effective integrated control system can often be developed and adapted to the local situation. This has happened in Peru (*11*), Nicaragua (*12*), Malaysia (*13*), and other parts of the world.

There is another development happening with the Food and Agriculture Organization (FAO) of the United Nations that will assist in meeting this dilemma. This is the newly proposed International Secretariat for Plant Protection. This has come about as a result of follow-up activities to the World Food Conference. This expanded Secretariat in Rome will provide new manpower and mechanisms to provide technological inputs for crop protection in developing countries. FAO and UNEP late last year developed a cooperative global plan for the development and implementation of integrated pest control (*14*).

This program has the stated objective of promoting the development and application of safer, more effective and more permanent plant protection procedures and techniques through the combined use of all compatible crop protection methods. The ultimate goal of this program is to attain the necessary production of essential foods and fibers in a manner that is economically feasible and which maintains environmental quality. By providing guidance and training in research, the development of sufficient expertise in the application of the integrated pest control concept in developing countries will hopefully be achieved so that they will then be able to develop and carry out integrated control programs for pests of major economic importance.

The scope of this program will initially be limited to a very few crops of major importance, such as cotton, maize/sorghum, and rice to ensure that the necessary breadth and depth in the organization and effort is obtained. A wide range of the appropriate expertise will be concentrated on research, demonstration, and training projects to prove the practical value of a new approach and to gain the confidence of the farmer in its adoption and widespread application.

There are many situations in these developing countries where the existing knowledge is adequate for initiating chemical control practices aimed at minimizing the use of pesticides and also for taking the beginning steps in incorporating these practices into the existing cultural and other procedures of their current control programs.

The first phase of this program will deal primarily with development of the major crop pest control system and with regional training, regional workshops, and with planning and initiation of a comprehensive regional program. The program is intended to extend over a sufficient number of years that enough time will be provided for strengthening extension and training services and to make farmers familiar and confident with the new control practices.

The program and the research work of the project will be coordinated with the activities pertaining to the field of integrated pest control of international institutes and foundations, i.e., IRRI, CIAT, CIMMYT, ICRISAT, IITA. In October of 1975, in Karachi, Pakistan, representatives of about 20 developing countries which produce cotton came together with integrated pest management experts from Europe and the United States to develop specific projects for the implementation of the global plan.

It appears that integrated pest management is being offered a large and open challenge in new opportunities. It is fortunate that at present the knowledge and techniques of its practice are being so intensively expanded and tested.

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